Effect of carbon dioxide insufflation on free internal thoracic artery flows: Is it a vasodilator?

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Background: This study was conceived to evaluate the effect of carbon dioxide insufflation on free internal thoracic artery flows.

Methods: We studied 56 consecutive patients who underwent coronary artery bypass grafting in which the left internal thoracic artery was anastomosed to the left anterior descending artery. The first 26 consecutive internal thoracic arteries were harvested as a pedicled graft (group 1), and the next 30 consecutive internal thoracic arteries were dissected by using the carbon dioxide insufflation technique (group 2). The internal thoracic artery harvesting was performed by 2 experienced surgeons by using the same instrumentation and technique. First, free flows of the internal thoracic arteries were registered after distal cutting of the vessel in both groups. After the first measurements, diluted papaverine was sprayed on the internal thoracic artery pedicle only in group 1, and then second measurements were registered after 15 minutes in both groups. Hemodynamic parameters were recorded with each measurement.

Results: The first free flow measurement was significantly higher in the carbon dioxide-insufflated internal thoracic arteries (group 2, 60 ± 32 mL/min; group 1, 28 ± 19 mL/min; $P < .05$). Although the second free flow measurement of the carbon dioxide-insufflated group was higher than in group 1, the difference was not statistically significant (68 ± 46 mL/min vs 53 ± 32 mL/min; $P = .53$).

Conclusions: Carbon dioxide insufflation of the internal thoracic artery is an efficient technique to increase the flow and seems to be safe, simple, and reliable. When the internal thoracic artery is harvested in a carbon dioxide-insufflated fashion, arterial spasm and reduced early flow may be avoided, even without vasodilator agents such as papaverine.

Periodic spasm of the internal thoracic artery (ITA) is a common experience in coronary artery bypass grafting. Perioperative spasm of the ITA may cause perioperative morbidity and even death in high-risk patients.¹ An established method of dealing with this problem is to spray papaverine solution on the ITA graft and to wrap the artery in a papaverine-soaked swab before grafting. Pediculated harvesting of the ITA is a well-known and safe method. However, to improve the graft flow and

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to avoid excessive thorax wall damage and related sternal infections, new techniques are being studied.²⁻⁵ Pediculated, skeletonized, and free ITA grafts are used by different surgeons.⁶

We have recently described a preparation technique of ITA by insufflating carbon dioxide into the endothoracic fascia along with the artery to form subpleural emphysema.⁷ This method of harvesting the ITA improves the ease of dissection, which helps to prevent arterial spasm. Carbon dioxide's vasodilator effect (hypercapnic vasodilatation) may reduce the risk of vasospasm of the arterial conduit during dissection.⁸ The aim of this study was to show a vasodilator effect of carbon dioxide insufflation on ITA flow.

Materials and Methods

Patients

This study comprised 56 patients who underwent harvesting of the ITA in preparation for coronary artery bypass grafting. Only elective operations were included in the study. Patients who were in hemodynamically unstable condition or had evidence of ischemia before the cardiopulmonary bypass; patients who had reoperation, concomitant valve operation, ventricular aneurysm resection, or other additional major cardiac procedures; and patients with chronic obstructive pulmonary disease were excluded from the study. The patients were divided into 2 groups by the techniques used for preparation of the ITA. In group 1 ($n = 26$), the ITA was dissected by pedicle, and in group 2 ($n = 30$) it was dissected by a carbon dioxide-insufflated technique. The 2 groups showed no significant differences due to the demographic variables (Table 1).

Technique

In the 56 patients who underwent ITA graft preparations, the left ITA was mobilized as a pedicled (group 1) or carbon dioxide-insufflated (group 2) vessel. Standard cardiopulmonary bypass with moderate hypothermia (28°C) was used in all cases. In the first group ($n = 26$), the ITA was prepared with the well-known pediculated harvesting technique. Preparation of the ITA in group 2 was performed with the carbon dioxide-insufflation technique described by Özkan and associates.⁷ During the preparation of the ITA in group 2 ($n = 30$), carbon dioxide was insufflated into the endothoracic fascia by using an injector with a 24-gauge needle to form subpleural emphysema. Carbon dioxide flow initially was set at 4 L/min and was increased or decreased by adjusting the regulator according to the amount of bleeding and the toughness of the tissue. This leads to easier dissection of the ITA with minimal use of electrocautery. In both groups, all the branches were clipped and cut along the ITA. Heparin 300 U/kg was administered intravenously 3 minutes before the transection of the ITA. The first flow (free flow) was calculated by leaving the artery bleeding for a minute. During the flow measurements, the heart rate, arterial systolic and diastolic blood pressures, and mean arterial pressures were recorded for each flow measurement. In the first group, after the first measurements, the ITAs were washed with papaverine solution (10 mg of papaverine in 20 mL of saline) and wrapped

TABLE 1. Patient demographic variables according to group: there was no statistically significant difference between groups

Variable	Group 1	Group 2
Sex (M/F)	24/2	27/3
Age (y)	57.9 $\pm$ 9.4	60.6 $\pm$ 10.8
BSA (m ²)	1.87 $\pm$ 0.17	1.85 $\pm$ 0.16
Diabetes	10 (38%)	13 (43%)
No. of distal anastomoses	2.85 $\pm$ 0.67	2.80 $\pm$ 0.61
Heart rate 1 (beats/min)	73.4 $\pm$ 10.9	75.3 $\pm$ 10
Heart rate 2 (beats/min)	78.9 $\pm$ 14	79 $\pm$ 12.9
MAP 1 (mm Hg)	87 $\pm$ 16.4	86.5 $\pm$ 15.7
MAP 2 (mm Hg)	84.3 $\pm$ 9.5	85.3 $\pm$ 12.5

BSA, Body surface area; MAP, mean arterial blood pressure.

with gauze. In both groups, second measurements were taken after 15 minutes.

Statistical Analysis

All flow measurement data are expressed as the mean $\pm$ SD. The unpaired *t* test was used for comparison between groups.

Results

The demographic and hemodynamic data of the 2 groups are shown in Table 1. There was no significant differences between the 2 groups with respect to body-surface area or the number of distal anastomoses. Both groups displayed no significant differences in heart rate and blood pressure measurements from flow 1 to flow 2. No patient showed early detrimental effects related to the dissection technique or the graft preparation method. There were no hospital deaths. In both groups the preparation of the ITA was performed with satisfactory graft quality, and all ITAs could be used in all patients and anastomosed to the left anterior descending artery. The first flow rate was greater in group 2 than in group 1 (60 $\pm$ 32 mL/min vs 28 $\pm$ 19 mL/min; $P < .05$). The differences between the groups were significant for the first measurements. In comparison of the second flow between the 2 groups, group 2 again showed a higher flow rate than group 1 (68 $\pm$ 46 mL/min vs 53 $\pm$ 32 mL/min; $P = .53$). The operative data of the groups, which were not statistically significant, are listed in Table 1. Postoperative electrocardiograms showed no specific changes. None of the patients' bleeding was due to the technique of ITA harvesting.

Discussion

The effects of various vasoactive agents on the size and blood-flow rate of ITAs have been of great interest to many investigators. Topical or intraluminal vasodilator agent administration was commonly preferred to eliminate artery spasm and to increase the ITA diameter and flow. ITA is a sensitive vessel and can be easily traumatized, and this

usually ends with artery spasm. Because of this, during harvesting many surgeons sometimes need to use diluted papaverine solution.

We decided to study carbon dioxide insufflation because of its hypercapnic vasodilator effect.⁸ In the carbon dioxide–insufflation technique, performed routinely in our clinic in recent years, in which carbon dioxide is insufflated into the intercostal spaces, the ITA can be better visualized, and fewer arterial manipulations are performed.⁷ This study demonstrated that carbon dioxide insufflation showed a vasodilator effect on ITA flow. The insufflation of carbon dioxide in the ITA bed facilitates easy and minimally traumatic harvesting by gas dissection. As the carbon dioxide is insufflated into the space by the described technique, the ITA stands out from the chest wall.⁷ In addition, dilation of the artery and its branches because of the carbon dioxide helps with easy visualization and division. This has helped to expedite the harvesting of the ITA without causing trauma and consequent spasm. Brundell and associates⁹ showed that carbon dioxide insufflation significantly increased peritoneal blood flow during laparoscopy in pigs. Brandt and colleagues¹⁰ also showed that carbon dioxide insufflation during colonoscopy increased colon blood flow in the dog.

Mills and Bringaze¹¹ suggested intraluminal papaverine administration because of its effects in increasing the free blood flow of the ITA; the diameter of the artery makes the anastomosis technique easier. Also, the side branches can be easily identified. In group 1, we did not prefer to use intraluminal papaverine because it is highly acidic and can cause intimal damage.

In our study, the first flow measurements were significantly higher in the carbon dioxide–insufflated group, and the second flow measurements were higher in group 2, but they were not statistically significant, although papaverine was used in group 1. We believe that this was due to the vasodilation performed by carbon dioxide insufflation, which avoided excessive electrocautery use and thermal injury. The most important and acceptable advantage of our carbon dioxide–insufflated technique is that we can harvest the ITA in a short time without vasodilator agents and with minimal electrocautery use, causing less injury to the thoracic wall.

Also, the time required for ITA preparation was shorter in the carbon dioxide–insufflated group compared with the standard technique. We experienced no ITA hypoperfusion

syndrome in either group but experienced higher blood flow in group 2.

Our study suffers from a number of limitations. The study was retrospective, with the 2 groups matched over different time frames, and it may not be a blind study. It is impossible to organize these kind of studies as completely blind. In our study, we asked whether carbon dioxide has a vasodilator effect on ITA flows or not. We did not mean that it is absolutely a vasodilator. This needs further study, but we observed more bleeding in the thoracic wall in group 2. In this study, it was shown that flow rates were increased by this method. This may be due to our method or to a direct vasodilating effect. We actually think that both have positive additive effects.

In conclusion, although our study was a retrospective and nonblind study, we believe that ITA harvesting with carbon dioxide insufflated into the endothoracic fascia creates less injury in the thorax wall, avoids arterial spasm without papaverine, and necessitates less time to prepare the graft. Future efforts should be directed toward investigating the effects of carbon dioxide with combined drugs and other gases on ITA characteristics.

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